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Optical double feed detection

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Optical double feed detection

Technical Field

The invention relates to a method for optically detecting a double feed in an apparatus for processing one or more types of sheet-like objects, particularly bank notes, where said objects are conveyed along a transport path in a moving direction. The invention further relates to a corresponding apparatus.

Background Art

In the processing of sheet-like objects where these objects are fed into an apparatus sequentially one by one and conveyed along a transport path, problems may occur due to a double feed of the objects. In a double feed two or more sheets are fed into the apparatus at the same time where one sheet can partially or completely overlap another sheet. In such cases, it may be significantly more difficult or even impossible to correctly process the objects. In,. for example, an apparatus for processing bank notes or other securities, it may be very difficult to correctly count, identify and/or authenticate the bank notes when a double feed occurs. The processing may even produce wrong results, if a double feed remains unnoticed. Therefore, double feed detection is an important feature in the processing of sheet-like objects.

Double feed detection is typically carried out with one or more sensor devices that are arranged on the transport path within the processing apparatus. Further sensor devices may also be included in the apparatus for determining other characteristics of the sheet-like objects. Classical optical doubles detectors are based on a mechanical roller system equipped with a position-sensing device. However, contact establishing sensor devices sometimes cause jams in the transport system, when the sheets are conveyed along the transport path. In order to reduce such jams, contact-free sensor devices have been introduced.

For example, the US 6,101,266 A discloses a device for identifying and validating bank notes. The device comprises three sensors, where each sensor has four differently coloured LED's (light emitting diodes) for illumination of a bank note and two photo cells, one on the same side of the bank note as the LED's for sensing light reflected from the bank note and one on the opposite side of the bank note for sensing light transmitted through the bank note. A plurality of correlation values is determined and then some or all of these multiple correlation values are combined to form a single overall correlation value. The identification decision or the double feed decision then are made based on this single overall correlation value.

Although the disclosed arrangement can be used for double note detection, it is dedicated for bank note identification/authentication. The results in detecting double notes are not always satisfactory.

Summary of the invention

It is therefore an object of the invention to create a method and an apparatus for optically detecting a double feed of sheet-like objects pertaining to the technical field initially mentioned, that yields more reliable results in detecting a double feed, particularly a lower number of double notes that are accepted as single notes and a lower number of single notes that are wrongly rejected as doubles.

The solution of the invention regarding a method for optically detecting a double feed is specified by the features of claim 1. According to the invention, the sheet-like objects are illuminated, a transmission image of a specific sheet-like object as well as a reflection image of the specific sheet-like object are produced by measuring the transmission intensities of radiation transmitted through and light reflected from the sheet-like object respectively. Then, a two-dimensional evaluation method is applied, where the first dimension is formed by the transmission intensities and the second dimension is formed by the reflection intensities.

The solution of the invention regarding an apparatus for optically detecting a double feed is specified by the features of claim 9. According to the invention, the apparatus for processing one or more types of bank notes has transport means for conveying the bank notes along a transport path in a moving direction. It further includes a detector for optically detecting a double feed of bank notes that comprises illumination means for illumination of the sheet-like objects, a transmission-type sensor for producing the transmission image of the bank notes and a reflection-type sensor for producing the reflection image. The apparatus further includes an evaluator which is built such that the two-dimensional evaluation can be carried out as explained above.

A preferred application of the invention is double feed detection of bank notes in an apparatus for bank note processing. However, the invention can advantageously be applied in other applications such as the processing of cheques or other securities or any other kind of sheet-like objects such as for example paper sheets. Therefore, the term "bank note", which is used throughout the rest of the description, shall, unless otherwise mentioned, not be considered restrictively but it shall be read to include all these types of sheet-like objects. With respect to the term "light" as used throughout the description, it shall, unless otherwise mentioned, not only include the visible part of the electromagnetic spectrum but any radiation with a wavelength in the electromagnetic spectrum.

By applying a two-dimensional evaluation method, the double feed decision can be based on a two-dimensional decision boundary instead on the one-dimensional higher/lower comparison of a single correlation value with a certain threshold. Moreover, the double feed decision is based on images (the reflection image as well as the transmission image) of the sheet-like objects instead of using just some spot measurements to decide on double feed. The resulting double feed decisions are much more accurate compared with the prior art.

Soil on the bank note not only affects the intensity of the light transmitted through the bank note but also the intensity of the light reflected from the bank note. In General, higher the degree of soiling is, the lower are the light intensities for transmission and reflection. A double feed decision based on both properties therefore decreases not only the number of over-critical (falsely rejected singles) but as well the under-critical (falsely accepted doubles) decisions.

This method for detecting double feed of bank notes can be applied in any kind of bank note processing apparatus. It could for example be applied in an apparatus, where the bank notes are fed manually one by one and processed one after the other. But preferably, this method is applied in a bank note processing apparatus, where the bank notes are sequentially and automatically fed into the apparatus and conveyed along a transport path in a moving direction and with a defined speed.

In a further preferred embodiment of the invention, first a position and an angle of the bank note with respect to the transport path are determined in a position analysis step when a specific bank note is conveyed along the transport path. Then, in a second step, the required images are produced by conveying the bank note past a multitude of sensor cells arranged in at least one line being perpendicular to the moving direction. Each line of sensor cells forms a sensor array positioned on the transport path. During the time interval, when the bank note passes the sensor cells, a plurality of sensor values for each sensor cell is determined in fast succession. The resulting image resolution therefore depends on the number of sensor cells in a sensor array, the travelling speed of the bank notes and the time interval between two successive sensor value readings.

To determine the position and the angle of a bank note before the double feed detection is carried out has the advantage that the imaging, that is the activation of the sensor cells, can be started and stopped exactly when the bank note passes the sensor cells. It further enables to scan only those areas of the transport path that actually are covered by the bank note, in case the bank note is smaller than the width of the transport path or it is skewed with respect to the transport path.

It is self-evident that these advantages could also be achieved by omitting the positioning analysis step and mechanically positioning the bank notes very precisely with respect to the transport path. But it would be mechanically demanding and, since such a precise positioning would require some time, it would undesirably lower the overall processing speed.

One single and strong light source may be utilised to illuminate the bank notes. But, in order to achieve an even light distribution on the bank notes, a multitude of small light sources such as for example light emitting diodes or light guides are used. In a preferred embodiment, the apparatus includes two illumination units each comprising a multitude of light sources arranged in line, thereby forming a first elongated illumination unit for illumination of a first surface of the bank notes and a second elongated illumination unit for illumination of a second surface of the bank notes.

While radiation with a wide range of wavelengths could be used to illuminate the bank notes, the usage of infra-red light is advantageous, because the majority of coloured inks that are used for printing bank notes and other securities appear mostly transparent in the infra-red domain. Hence, printings on bank notes do not or only minimally disturb the double note detection by falsifying the radiation intensity measurements. Particularly preferred is radiation in the near infra-red domain, that is radiation with a wavelength between 700 nm (nano meter) and 1300 nm.

The sensor cells preferably are arranged such that they form a transmission-type sensor for measuring the light transmitted through the bank note and a reflection-type sensor for measuring the light reflected from the bank note.

The elongated illumination units as well as the sensor arrays are arranged on the transport path with their longitudinal axes perpendicular to the moving direction such that the light sources as well as the sensor cells are distributed over the whole width of the transport path.

Each sensor cell for measuring light intensity not only comprises a light sensitive device such as for example a photodiode or a CCD (charge coupled device), but also optical means for directing and/or focussing the transmitted or reflected light onto the light sensitive device. The optical means can comprise any kind of lenses. The usage of rod lenses arranged as a rod lens array is preferred because of the compact designs that can be realised with them and because they are rather inexpensive compared with conventional lenses. The usage of such rod lens arrays is well known in the art of 1:1 imaging.

Although the transmission and the reflection images may be captured with two different sensor arrays, it is preferred that only one sensor array is provided. That is one array of sensor cells forms the transmission-type sensor as well as the reflection-type sensor. In this case, the double feed detector further comprises a controller for controlling the illumination units such that they are switched on and off alternately. Hence, the single sensor array measures the intensities of light transmitted through or reflected from the

bank notes also in an alternating manner. The controller therefore may be designed to additionally control the sensor array or the storing of the measured values in a memory respectively.

Generally, it would be possible to evaluate the entire transmission and reflection images to detect a double feed. However, this would have drawbacks. On the one hand, it would require a considerable amount of computing and on the other hand, some regions of the bank note that are not particularly suited for doubles detection, would be taken into account. Such regions for example include dark prints, foils (e. g. holograms) and threads or damages of the bank note. Hence, the detection accuracy can be further improved by determining a set of dedicated test spots for the currently processed bank note and deciding on double feed by solely taking these test spots into account.

The test spots could be chosen randomly or according to a given rule like for example: the test spots are chosen as the intersection points of the grid lines of a regular grid laid over the bank note. Still some of these test spots would not be particularly well suited for doubles detection.

A preferred way of determining these test spots is image processing of the transmission and the reflection image with the goal to choose the test spots such that the transmission and reflection intensities measured for these spots are meaningful regarding a double feed decision. Meaningful test spots are chosen by taking into account the position and the angle of the bank note with respect to the transport path as well as the type of bank note that is to be tested. The meaning of the latter means that certain known parameters of the type of the bank note, such as for example the distribution of prints or other features such as holograms or metal stripes on the bank note, the material of which it is made of, the note's size or other properties of the note are considered when the test spots are determined by image processing.

The test spots are particularly positioned such that they are located outside of a bank note area that is not well suited for doubles detection. Such an area is designated herein as an exclusion area. The exclusion area includes for example areas of the bank note with a dark

print, foils (e. g. holograms) or threads (e. g. metallic threads). Even though the ink may appear mostly transparent for the utilised light it can falsify the measurements. The exclusion area may further include an area within a given maximum distance to an edge of the bank note because these areas may be mechanically damaged. To take dog-ears into account, the exclusion area additionally may include a particularly shaped area in each corner of the bank note such as for example a triangular, rectangular or square area or it could even be a sector-like area with the center of the circle in the corners of the bank note. This particular choice of the test spots has the advantage, that the intensity measurements in the bank note areas outside of the exclusion areas are mainly attributed to the structure of the paper, in particular the thickness of the paper, which is exactly what is needed to detect a double feed. The basic principle of double detection is the detection of an abrupt change of the light intensities, particularly the transmission intensity.

In order to take account of smaller bank notes, the test spots are, in a preferred embodiment of the invention, partitioned into overlapping regions of the bank note, e. g. five regions, one at the top, bottom, left and right respectively and a central region that overlaps the other four regions.

To decide on double feed in such cases, first an independent double feed detection result is determined for each region separately and independently of each other region. Then, in a second step, an overall double feed detection result is determined by combining the independent double feed detection results of each region in a suitable way. One way would be to decide on double feed for a particular bank note, if it has been decided on double feed for at least one region (or a minimum number of regions) of this bank note. This method corresponds to a kind of OR-combination of the independent detection results. Another way would be to implement some kind of AND-combination including for example a suitable weighting of the independent detection results.

Applying such a method enables to detect a complete as well as a partial overlap. In the case of a partial overlap of two or more bank notes, the decision on double notes can further be backed up by a boundary analysis.

To obtain the information regarding the bank note type for a specific bank note to be tested, several possibilities exist: for example to manually set the type when a certain note is fed into the processing apparatus, to feed only a certain type of bank note into the apparatus or to provide the apparatus with a stacker for each type of bank note, where the apparatus can choose a particular stack thereby "knowing" which type of bank note is deposited in that stacker.

These methods require an additional expenditure of sorting work, when the apparatus should be capable of processing more than one type of bank notes. Therefore, in a preferred embodiment of the invention the type of the bank note to be tested is determined, that is identified, automatically during a validation step, that is carried out before the double feed detection is carried out. Moreover, the double feed detection is only carried out if the bank note has correctly been validated previously.

The validation step is carried out with a validator that is arranged too on the transport path of the apparatus. Since the double feed detection is only carried out, if the bank note could have been validated correctly, the validator and the detector are built such that the bank note validation is carried out before the double note detection. For this purpose, the apparatus could be built such that the detector is arranged on the transport path after the validator with respect to said moving direction. In this case, the validator would have to include separate sensor means for sensing certain bank note characteristics in order to validate the bank note. In another preferred embodiment of the invention, the validator utilises the light intensity measurements of the doubles detection means to validate the bank notes, that is the validator uses the transmission and the reflection images captured with the transmission-type sensor and the reflection-type sensor.

The validation step primarily includes an identification of the bank note. Though, additionally to the identification of the bank note type, the validation step can also comprise an authentication of the bank note. Nevertheless, an authentication of the bank note can also be carried out independently of the bank note identification at any later

stage, i. e. between identification and doubles detection, parallel to the doubles detection or even after the doubles detection.

Other advantageous embodiments and combinations of features come out from the detailed description below and the totality of the claims.

Brief description of the drawings

The drawings used to explain the embodiments show:

Fig. 1	An apparatus for processing bank notes according to the invention;
Fig. 2	a schematic diagram of the detection means including illumination;
Fig. 3	a bank note on which a set of test spots is indicated on the basis of which the double note detection is carried out;
Fig. 4	an example of a grouping of the set of test spots into several, overlapping groups;
Fig. 5	a schematic plot of a two-dimensional evaluation chart with a plurality of intensity measurements showing a two-dimensional decision boundary for deciding on double feed;
Fig. 6	a flow chart showing the method of detecting a double feed in the apparatus shown in fig. 1 and
Fig. 7	a flow chart showing the double feed detection steps of fig. 6 in more detail.

In the figures, the same components are given the same reference symbols.

Preferred embodiments

In fig. 1, an apparatus 1 for processing bank notes is shown. The apparatus 1 comprises transport means 2, schematically represented by two Rollers, for conveying the bank notes along the transport path 3 in the moving direction 4. A bank note that is conveyed along the transport path 3 passes an imaging sensor 5 which captures two images of the passing bank note: the first image is produced by sensing light that is transmitted through the bank note and the second image is produced by sensing light that is reflected from the bank note.

Based on these images, a validator 6 attempts to identify and/or authenticate the bank note. If the bank note has not correctly been validated, the bank note is rejected which is for example done by diverting it onto the rejection path 3.1 by means of a switchgear 8. If the bank note has correctly been validated, the detector 7 decides, whether a double feed, where two or more bank notes overlap partially or completely while being conveyed along the transport path 3, exists or not. The doubles detection again is based on the output of the imaging sensor 5, that is by evaluating the transmission and the reflection images. If the detector 7 decides, that there does not exist a double feed, the bank note is accepted and the switchgear 8 directs the bank note onto the default path 3.2 for further processing (not shown). If the detector 7 decides, that a double feed exists, the bank note is rejected and diverted either onto the rejection path 3.1 or onto any other alternative path different from the default path 3.2 and the rejection path 3.1.

Although not shown, the apparatus 1 may include further means, e. g. further sensor means such as for example capacitive or magnetic sensors for sensing additional characteristics of the bank notes.

Fig. 2 shows a bank note 10 which is conveyed along the transport path in the moving direction 4 thereby passing the imaging sensor 5. While the imaging sensor 5 and the bank note 10 are shown in a side view, only one sensor element is shown. However, the imaging sensor 5 includes a plurality of sensor elements such as that shown in fig. 2, arranged in

line, so as to form a sensor array parallel to the surface of the bank note 10 and perpendicular to the moving direction 4.

The imaging sensor 5 comprises a light source 11.1, arranged below and emitting light in the direction of the lower surface 10.1 of the bank note 10. To achieve the goal that the narrow stripe of the bank note 10 that is currently scanned is illuminated as uniformly as possible, a lens 12 for defocusing the light emitted from the light source 11.1 is positioned between the light source 11.1 and the bank note 10. On the upper surface of the bank note 10, the light from the light source 11.1 that has traversed the bank note 10 is passed through the lens 13 and directed onto the light sensor 14. The light sensor 14 includes for example a phototransistor or a CCD device. All of the light sensors 14 of the imaging sensor 5 form a sensor array with a resolution in the range of about 1 to 20 pixels per mm. However, a resolution of about 5 to 10 pixels per mm is preferred.

The lens 13 is for example a rod lens. The rod lenses of all the sensor elements of the imaging sensor are aligned thereby forming a rod lens array which enables a simple way to capture a 1:1 transmission image of the bank note 10. The number of rod lenses is in the range of some dozens to several hundreds. It is to note that the number of light sensors 14 does not have to be the same as the number of rod lenses 13. It is further to note that, since additional optical means such as the lens 12 are used to achieve a highly uniform illumination of the bank note, the number of light sources 11 is typically much lower than the number of rod lenses 13 and light sensors 14.

The sensor element shown in fig. 2 further comprises two light sources 11.2, 11.3 which are arranged above the upper surface 10.2 of the bank note 10 on either side of the lens 13. They emit light onto the upper surface 10.2 of the bank note in an angle of about 45 degrees. Some of the light that is reflected by the upper surface 10.2 of the bank note passes the lens 13 and produces a continuous reflection image of the upper surface 10.2 of the bank note 10 on the array of light sensors 14.

To distinguish between transmission and reflection measurements, the light sources 11.1, 11.2, 11.3 are operated in multiplex mode, that is the light source 11.1 is switched on and

off rapidly in alternation with the light sources 11.2 and 11.3, which are switched on and off at the same time. To ensure that the transmissive and the reflective sampling points represent corresponding portions of the document, the switching frequency must be high relative to the light sensor array resolution as well as relative to the transport speed of the bank note in the moving direction 4. Additionally, the apparatus comprises storing means 15 for storing the multitude of measured light intensity values for each scanned, narrow bank note stripe. The intensity values are measured with the light sensors 14 and are represented by a voltage, a current, a charge or any other electrical measures, are read out with suitable means and then stored in the storing means 15. With a resolution of about 8 pixels per mm, the number of intensity measurements per image for a 130 mm by 70 mm bank note is about 600'000.

To control the switching of the light sources and the correct timing for storing the transmission and the reflection intensities respectively, the detector 6 further includes a controller 16 connected to the light sources 11.1, 11.2, 11.3 and the light sensors 14. The controller 16 may also be used for additional purposes.

Although the imaging sensor 5 is shown to form a mechanical unit, the capturing of the images may also be accomplished with two different light sensor arrays which are arranged at different locations of the transport path. Since the position and the angle of the bank note is determined first, the separately produced transmission and reflection images can be combined so that they correspond properly.

In fig. 3, a bank note 10 is shown. Several prints on the bank note 10 are shown, for example a currency sign in two corners, an elliptic and a rectangular area with a dark print 20. The bank note may further include other features like thin metal stripes, holograms or any other known features, particularly security features of bank notes.

While hundreds of thousands intensities are measured to produce an image of the bank note, only a small part of these measurements are used to detect double notes. The areas of the bank note 10 that are used for doubles detection, are shown as a multitude of test spots 21 in fig. 3. The number of test spots 21 is in the range of about 20 up to 1000,

depending on the requirements regarding evaluation time and accuracy. Each of these test spots 21 can comprise one or more pixels of the transmission or reflection image respectively and the test spots 21 are more or less evenly distributed over the whole bank note. However, no test spots 21 are positioned within the so-called exclusion areas. These exclusion areas include the dark prints 20, a square area 23 in each corner of the bank note 10 and a rectangular area 24 along the edges of the bank note 10. These areas are excluded from consideration for double note detection, because the probability that the exclusion areas falsify the double note detection is higher than for other areas of the bank note 10. Dark prints 20 may falsify the detection result by lowering the intensity measurements and the square areas 23 as well as the rectangular areas 24 may falsify the detection result because of physical defects of the bank note 10 which typically appear in these areas with a higher probability than in other areas of a bank note.

Fig. 4 again shows the bank note 10 with the test spots 21. In order to group the test spots 21 in different regions which are evaluated separately, two separating lines 25.1, 25.2 and a separating rectangle 26 are shown. The test spots 21 are grouped into five overlapping regions by the separating lines 25.1, 25.2 and the separating rectangle 26. The regions comprise a top region 27.1, a bottom region 27.2, a left region 27.3, a right region 27.4 and a center region 27.5. The regions 27.1 – 27.5 partially overlap which means that some of the test spots 21 belong to more than one region 27.1 – 27.5.

As mentioned before, the evaluation of the transmission and the reflection image in order to detect double notes is done with the light intensities measured for the test spots 21 as shown in fig. 3 and 4. That is, for each test spot 21, the transmission intensity is drawn against the reflection intensity, leading to an intensity spot 28 for each test spot 21. Doing this for a plurality of single and double bank notes with different degrees of soiling, results in an intensity spot distribution similar to the one shown in the graph of fig. 5 with the horizontal axis 32 representing the reflection intensity and the vertical axis 33 representing the transmission intensity of the test spots 21. Measurements have shown, that the intensity spots 28 form two clusters, a cluster 29 with the intensity spots for single notes and a cluster 30 with the intensity spots for double notes. The clusters 29, 30

have an elongated shape with a longitudinal axis 29.1, 30.1 respectively. The clusters 29, 30 are approximately separable by a linear decision boundary 31 which is a simple line drawn between the two clusters. The decision boundary 31 is approximately parallel to the longitudinal axes 29.1, 30.1 of the clusters 29, 30.

This particular orientation of the clusters 29, 30 and the decision boundary 31 results from the fact that a higher degree of soiling lowers not only the transmission intensity for a certain test spot 21, but also the reflection intensity for this test spot 21 is lowered.

In order to decide whether a double feed exists, the transmission intensities and the reflection intensities for the defined set of test spots have to be measured and a graph similarly to the one shown in fig. 5 has to be drawn separately for each region of the bank note. Then an independent double feed detection result for each region is determined. If all or most of the intensity spots 28 of a specific bank note region are located above the decision boundary 31, it is decided that no double feed exists for this region. If it is located below the decision boundary 31, it is decided that this region represents a double feed.

The independent double feed detection results for each region then are combined in a suitable way to determine an overall double feed detection result.

It is to note that the evaluation of the measured intensities is performed by a processor, for example a microprocessor. The controller 16 could for example be used to perform this evaluation.

The flowchart of fig. 6 and 7 show the method of detecting a double feed in the apparatus of fig. 1. First, the image capturing 40 of the transmission and the reflection images is carried out. Then, a bank note registration 41 is performed, where the spatial orientation of the bank note, that is the position and the angle of the bank note with respect to the transport path, is determined. In a third step follows the validation 42 of the bank note. If the validation result 43 is negative, that is the bank note has not correctly been validated, the bank note is rejected 44. If the validation result 43 is positive, the double note detection 45 is performed by evaluating the transmission and the reflection images as

explained above, considering the results of the image capturing 40, the registration 41 and the validation 42 of the bank note under test. This evaluation comprises the test spot extraction 47 for each region, where specific parameters 46 of the type of the specific bank note, which is determined during the validation 42 step, are taken into account. Then, the region-wise classification 48 follows resulting in a vector of region decisions 49. Each region decision can be accompanied by a confidence value representing how trustworthy this particular region decision is.

Eventually, the overall double note detection result 50 is determined. If the confidence for non double feed is high enough, which means that no double feed has been detected, the bank note is accepted and a further processing 51 can follow. If the confidence for singularity of the bank note is not high enough, which means that it has been decided on double feed, the bank note is rejected 44.

In summary, it is to be noted that, since the number of over-critical as well as under-critical decisions can be reduced, the invention enables a highly robust detection of double feeds in an apparatus for processing sheet-like objects such as bank notes or other securities.

List of reference symbols

1	apparatus
2	transport means
3	transport path
3.1	rejection path
3.2	default path
4	moving direction
5	imaging sensor
6	validator
7	detector
8	switchgear
10	bank note
11.1, 11.2, 11.3	light source
12, 13	lens
14	light sensors
15	storing means
16	controller
20	dark print
21	test spots
23	square area
24	rectangular area
25.1, 25.2	separating line
26	separating rectangle

27.1, 27.2, 27.3, 27.4, 27.5	region
28	intensity spot
29, 30	cluster
31	decision boundary
32	horizontal axis
33	vertical axis
40	image capturing
41	registration
42	validation
43	validation result
44	rejected
45	double note detection
46	specific parameters
47	test spot extraction
48	region-wise classification
49	region decisions
50	overall double note detection result
51	further processing

Claims

1. Method for optically detecting a double feed in an apparatus for processing one or more types of sheet-like objects, particularly bank notes, characterised in that said sheet-like objects are illuminated, a transmission image of a specific sheet-like object of said sheet-like objects is produced by measuring transmission intensities of light transmitted through said specific object and a reflection image is produced by measuring reflection intensities of light reflected from said specific object where said double feed is detected by applying a two-dimensional evaluation method, a first dimension of said two-dimensional evaluation method being formed by said transmission intensities and a second dimension of said two-dimensional evaluation method being formed by said reflection intensities.

2. The method as claimed in claim 1, characterised in that said sheet-like objects are sequentially fed into said apparatus and conveyed along a transport path in a moving direction where first a position and an angle of a specific sheet-like object with respect to said transport path are determined and where second said specific sheet-like object passes a multitude of sensor cells arranged in at least one line being perpendicular to said moving direction, said transmission intensities and said reflection intensities being measured by determining a multitude of sensor values for each sensor cell in fast succession while said specific sheet-like object passes said sensor cells.

3. The method as claimed in claim 2, characterised in that said sheet-like objects are illuminated with infra-red light.

4. The method as claimed in any of claims 2 or 3, characterised in that a set of dedicated test spots is determined for said specific object and said two-dimensional evaluation for said specific sheet-like object is solely carried out for said set of test spots.

5. The method as claimed in claim 4, characterised in that said test spots are defined by image processing said transmission image and said reflection image, thereby considering said position, said angle and known parameters of an object type of said specific sheet-like object.

6. The method as claimed in claim 5, characterised in that said test spots are determined such that they are positioned outside of an exclusion area of said specific object, said exclusion area comprising at least one of the following object areas:

a) an area of said specific object with a dark print, a foil, a hologram or a thread,

b) an area within a given maximum distance to an edge of said specific object or

c) an area, particularly a rectangular area, in each corner of said specific object.

7. The method as claimed in any of claims 4 to 6, characterised in that said test spots are grouped in a plurality of overlapping regions of said specific object, where first an independent double feed detection result is determined for each region and second an overall double feed detection result is determined by combining said independent double feed detection results of each region.

8. The method as claimed in any of claims 5 to 7, characterised in that said specific object is validated in a first step and said double feed is detected in a second step only if said specific object has correctly been validated, where said object type of said specific object is determined during said first step of validating said specific object.

9. Apparatus for processing one or more types of sheet-like objects, particularly bank notes, having transport means for conveying said sheet-like objects along a transport path in a moving direction and a detector for an optical detection of a double feed of said objects, said detector comprising illumination means for illumination of said sheet-like objects, particularly with infra-red light, a transmission-type sensor for producing a transmission image of said objects by measuring transmission intensities

of light transmitted through said objects, a reflection-type sensor for producing a reflection image of said objects by measuring reflection intensities of light reflected from said objects and an evaluator which is built such that a two-dimensional evaluation can be carried out where a first dimension is formed by said transmission intensities and a second dimension is formed by said reflection intensities.

10. Apparatus as claimed in claim 9, characterised in that said illumination means comprise a first elongated illumination unit for illumination of a first surface of said sheet-like objects and a second elongated illumination unit for illumination of a second surface of said sheet-like objects, each illumination unit preferably comprising a multitude of light sources arranged in line.

11. The apparatus as claimed in claim 10, characterised in that said transmission-type sensor comprises an array of sensor cells and said reflection-type sensor comprises an array of sensor cells where said elongated illumination units and said arrays of sensor cells are arranged perpendicular to said moving direction of said transport path.

12. The apparatus as claimed in claim 11, characterised in that each sensor cell comprises a light sensitive device for measuring said intensities of light and optical means, particularly a rod lens, for directing said transmitted or reflected light onto said light sensitive device.

13. Apparatus as claimed in any of claims 11 or 12, characterised in that said detector comprises exactly one array of sensor cells forming said transmission-type sensor as well as said reflection-type sensor and a controller for alternately switching said illumination units on and off and alternately measuring said intensities of light transmitted through or reflected from said sheet-like objects respectively.

14. The apparatus as claimed in any of claims 10 to 13, characterised in that it comprises a validator for a validation of said objects, said validator and said detector being built such that said validation is carried out before said optical detection and such that said optical detection is carried out only if said validation of said objects has been carried out correctly.

Abstract

In an apparatus (1) for processing bank notes or other sheet-like objects, the bank notes are conveyed along a transport path (3), thereby passing sensor means (5). A transmission and a reflection image of the bank note are captured by illuminating the bank notes and measuring the transmittive and reflective light intensity of light with a high resolution. Based on these images, a validation (6) of the bank notes is carried out. After the validation, a double feed detection (7) is performed by evaluating the transmission and the reflection intensities for a predefined set of test spots with a two-dimensional evaluation. If it is decided on double feed, the bank notes are rejected (3.1). Otherwise the bank notes are accepted and further processed (3.2). Because of the additional dimension in the evaluation compared with known double detection methods, the invention enables a more robust double note detection also in cases with different degrees of soiling of the bank notes.

(Fig. 1)

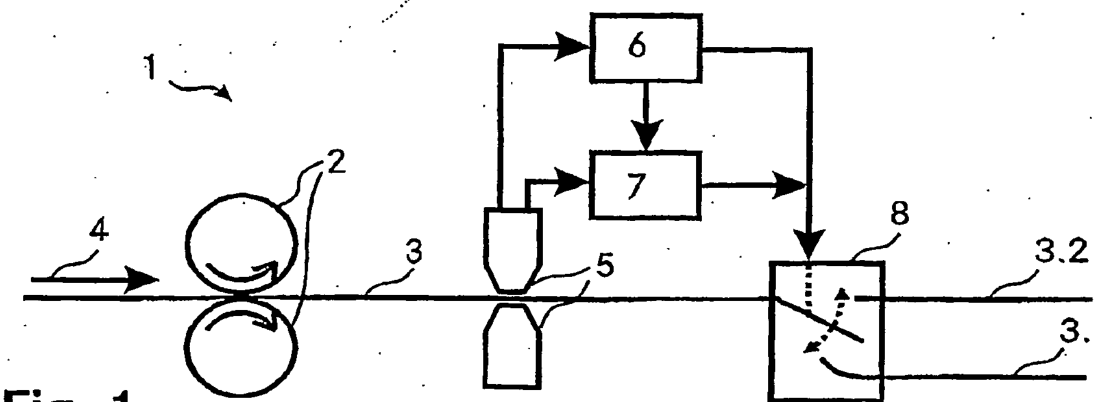

Fig. 1

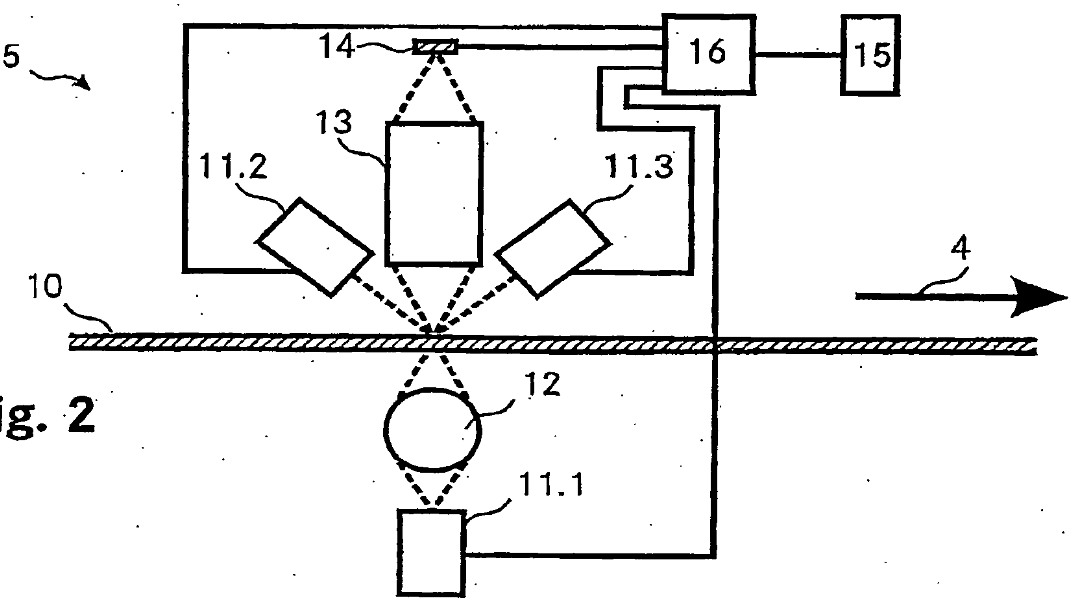

Fig. 2

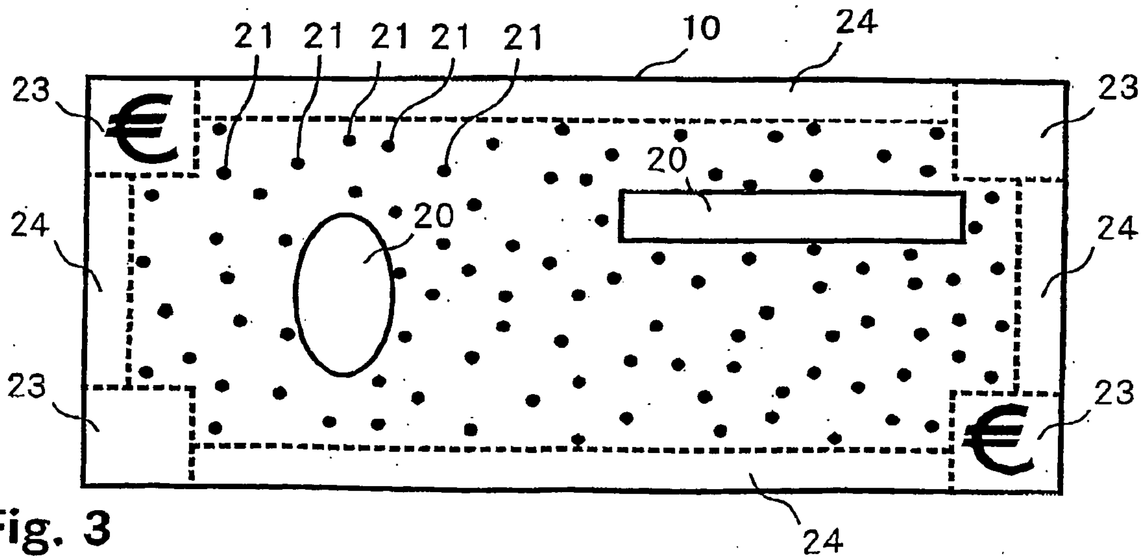

Fig. 3

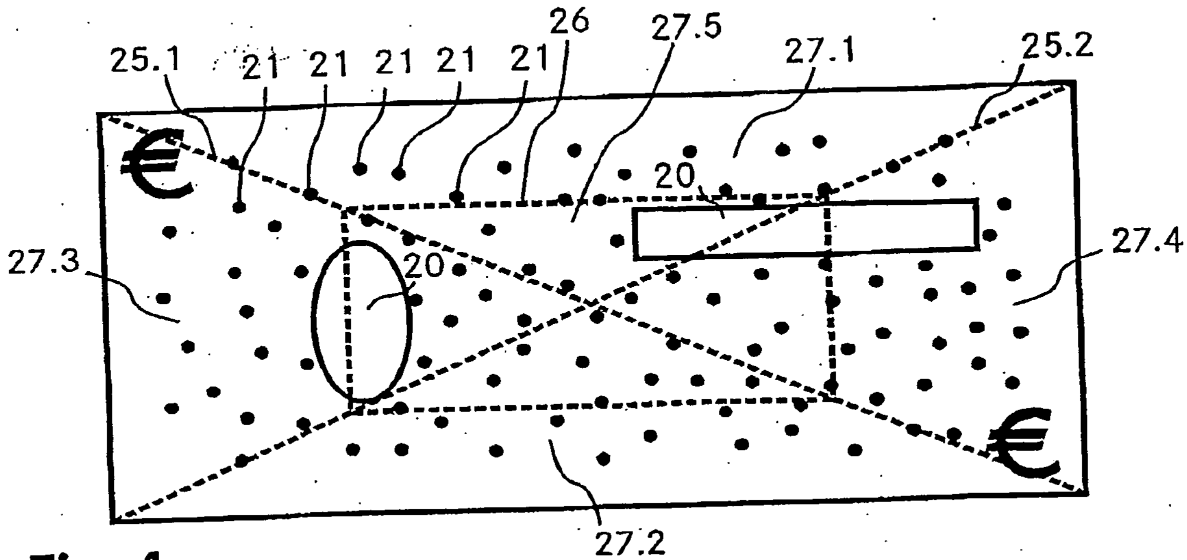
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Fig. 4

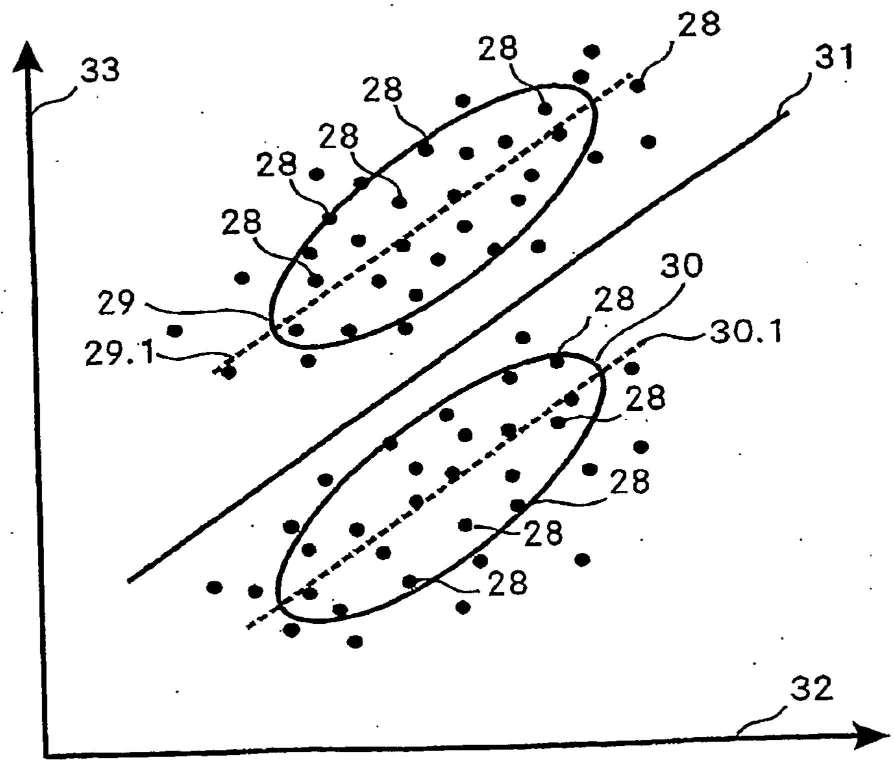
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Fig. 5

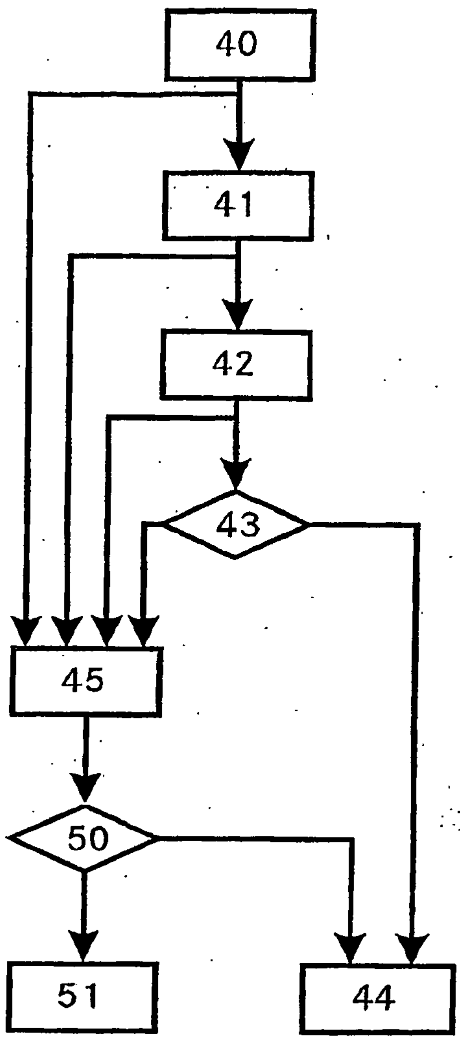

Fig. 6

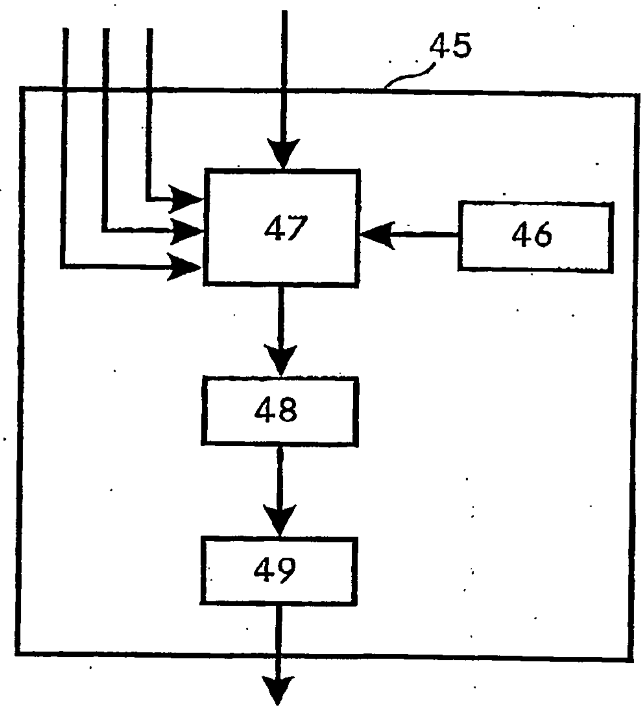

Fig. 7

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